

Study on the Collimated Jets of 19P/Borrelly

Abstract:

On September 22, 2001, Deep Space 1 spacecraft [DS1] flew by comet 19P/Borrelly. Presented in this proposal is a study of the Miniature Integrated Camera and Spectrometer (MICAS) images found in the Planetary Data Systems: Small Bodies Node archives. These images from the Deep Space 1 mission show that the dust jets of 19P/Borrelly, originating from the comet's nucleus, demonstrate characteristics of collimation.

The DS1 mission provided scientists with the first high-resolution images of a Jupiter-family comet and its surrounding environment. These images include a detailed view of the surface of the comet as well as two types of dust features: broad fans and narrow jets that suggest collimation. Once the rate and angle of expansion of the jet, and the intensity of the dust have been found, the models proposed by (Farnham, 2008), (Yelle et al, 2004) and Davidson will be tested to see if they can clearly reproduce the data found from the observations of the Deep Space 1 spacecraft. With more research into this cometary mechanism we will be able to show how a simple model will be applicable to jets on other comets. Looking at the images from both the MICAS instrument on the DS1 spacecraft and ground-based, we can clearly see that 19P/Borrelly is our greatest example of a collimated jet of gas and dust, due to the jet's location on the comets rotation axis. Not having to create a shape model allows for a more accurate analysis of the jet's characteristics. Using the information from the jets of 19P/Borrelly, scientists can make assumptions on the material and physical conditions inside of the

comet. This research can lead to more precise measurements of the composition of comets, and a greater understanding of the solar system many years ago. As a College Student Investigator for Planetary Data Systems I will analyze the DS1 high-resolution images of 19P/Borrelly for the density distribution of the material contained in the jet and test the proposed models for the mechanism.

Introduction:

The Deep Space 1 (DS1) mission was intended to test and validate high-risk technologies that are important for future missions. In addition to this primary goal, the secondary objectives were to obtain images and spectra of the near-Earth asteroid 9969 Braille (1999 K2) and the comet 19P/Borrelly. On September 22, 2001 at 22:30 UT Deep Space 1 flew by comet 19P/Borrelly near the south ecliptic pole. This was 8 days after perihelion, at a heliocentric distance of 1.36 AU and a geocentric distance of 1.48 AU. The closest approach during the flyby was 2171 km from the comet's surface with a relative velocity of 16.58 km/sec. The Miniature Integrated Camera and Spectrometer (MICAS) took both optical images (from 0.5 to 1.0 microns) and spectra (1.3 to 2.6 microns) during the approach. The visible wavelength images will be used in this study because problems with the calibrator of the spectra prove this data questionable for use. Between August 25th and 10 hours before closest approach on September 22nd DS1 performed 11 imaging sessions with the spacecraft at distances from 40.3×10^6 km to 6×10^5 km from the comet. These far encounter sequences, which are labeled far01 – far11 in the PDSSBN archives, were acquired with the visible wavelength channel of the MICAS instrument. The primary encounter imaging sequence, which is labeled near_ccd

in the archives, collected images with the VISCCD during the final 10 hours of approach to 85 min before closest approach. Whereas the far encounter images have been divided in the dataset directory by date, the near_ccd images are all included together.

The most distinguishable feature in the images of Borrelly is the large jet projecting radially outward in the sunward direction. This is present in the MICAS images as well as the ground based photometry. The difference in pressure between the subsurface gases and the vacuum of space causes the gas and dust to be expelled from subsurface cavities and outward. The gas and dust is then decoupled due to the rapid drop in density as the gas and dust expand out of the nucleus, and the dust is allowed to continue in a collimated beam into space. (Yelle et al, 2004) Cometary jets tend to be narrow, and can last for months, but can also change their appearance or direction on smaller timescales. Narrow jets are highly collimated flows, which produce a high-density region expanding radially away from the nucleus. (Farnham, 2008) Although the processes are similar, this should not be confused with the collimation of light where the rays are nearly parallel and spread slowly as the beam propagates. Although jets are primarily radial, they can show curvature at increasing distances from the nucleus due to rotation of the comet, or exponential expansion. This will be important in determining the expansion rate due to the difference in pressure. The major jet of comet Borrelly is located on the comet's spin axis, which allows us to easily measure the collimation and neglect any effects due to rotation. This shows that Borrelly is the ideal test case for evaluating the models for this cometary mechanism.

There have been many mechanisms proposed to explain the collimation process, including ones that discuss the topography of the surface of the comet, or theories on

trenches, craters, or cavities below the surface. This is the first extensive testing done to explain the process behind the collimation, but there is much information available from the images of 19P/Borrelly to suggest that the observational data can be reproduced. The “Venturi Effect” which is suggested in (Yelle et al, 2004) involves a supersonic acceleration of a gas fluid through a small hole in the surface. If the surface material is diffuse allowing gas and dust through a wider area, or if there is a large number of smaller pores, then all vents can contribute to the single jet. The smaller columns of gas and dust behave in the same manner, except that when the gas expands outward in all directions, it is met with equal and opposite force from the gas pressure of the surrounding columns. We will assume reasonable physical parameters or use data from other scientific studies to constrain the models. If the mechanisms proposed by Roger Yelle, Tony Farnham, or the Davidson Group cannot replicate the observational data for the jet of 19P/Borrelly, changes will be made to the model or to the physical parameters and we will try to reproduce the observational data once more. It is possible that only the introduction of complex hydrodynamic equations will allow for a more perfect model, but before that we must check the model against the observational data found by studying the DS1 images of Borrelly.

Research Question:

By studying the Deep Space 1 images of comet 19P/Borrelly, how well can we characterize the collimation that the major jet exhibits? Is it then possible to reproduce the observational data using the proposed models for this cometary mechanism?

Methods:

The majority of the research will come from studying the images found in the DS1/MICAS Uncalibrated VISCCD and SWIR Dataset on the PDSSBN archive website. I will primarily examine the near_ccd fits files which were taken during the final 10 hours of approach. All of the data will be analyzed using the Interactive Data Language (IDL) on the Linux operating system, which is available in the UMD CCS undergraduate computer lab. Some preliminary work will be done using the program SAO Image, but all scientific data will be gathered using the IDL program. The medium resolution images from approach will be analyzed first to improve upon the research method, and then the high-resolution images taken during the spacecraft's closest position will be examined with greater detail.

Assuming that the particles are in a steady state during the flyby imaging, we can deduce that the ground-based observations show the same result as the DS1 spacecraft images. With this wide range of resolutions and angles of observation, we can characterize the jet from many different directions and distances. The density distribution of dust particles can be found from the intensity of the light that is scattered when the jet is in the sunward direction. We will assume that the density distribution of the dust can be found with the brightness in the images and the 3-D stereo information during flyby. The brightness will be measured at many points along the jet to search for any variation that may be indicative of layering or inhomogeneity in the cometary nucleus. Using this information, I can make conclusions on the composition of the jet. A 3-Dimensional distribution of the dust will be created using the stereo information gathered during the spacecraft's flyby. It may be necessary to create a geometric model

for the comet Borrelly using the ephemeris information and the IDL program, but since the jet is on the rotation axis, there is no dependence on the orientation of the comet. Digital elevation models are also present in the PDS directory. An intensity map detailing the dust in the jet for each image will be combined with the rate and angle of expansion of the jet, and stereo information to create an accurate representation of the dust inside the jet. This result of my analysis of the observational data will be compared with a similar prediction from the models using reasonable physical parameters, or scientific data from other studies (to be cited later). If the model can reproduce what is seen by the DS1 MICAS instrument, and ground-based observations, it can then be suggested that the model can accurately explain the cometary mechanism that created the collimated jet on comet Borrelly. If the simple models are insufficient, then as a last resort they may need to be evaluated taking into account more complex laws of hydrodynamics. This is beyond the scope of this project, but the jet characterization will provide constraints on the models that others will have to account for. With a model of a collimated jet, we will be able to learn more about this cometary mechanism and more about jets on other comets.

Timeline:

January 2009

- Finish final draft of Proposal by the 19th
- Practice Presentation with PDS mentors on Jan 21st
- Create Power Point Presentation for GSFC Meeting
- Professional Meeting at Goddard Space Flight Center at 4:00pm on the 26th

February 2009

- Continue work with fits images

March 2009

- Create Power Point presentation for PDS Management teleconference

April 2009

- Present proposal to PDS Management Council, via teleconference
- Create Rough Draft of Abstract and submit to Mentor

May 2009

- Finish analysis of MICAS fits files (specifically jet information)
- Finish draft of Abstract and submit to Mentor for professional meeting

June 2009

- Submit Abstract to DPS, AGU, etc. Mentor's Choice
- Start rough draft of final report

July 2009

- Recreate Observational Data using model

August 2009

- Continue to evaluate proposed model for collimation mechanism

September 2009

- Finish final draft of report to present at Professional Meeting
- Work on Presentation of Report for Professional Meeting

October 2009

- Present Paper at Professional Meeting (Puerto Rico)

May 2010

- Final Summary Due to PDS CSI office by the 21st

References

Yelle, R. V., L. A. Soderblom, J.R. Jokipii. Formation of jets in Comet 19P/Borrelly by subsurface geysers. 2004, Icarus 167, 30.

Farnham, Tony. Coma Morphology of Jupiter Family Comets. 2008

Ho, T. M., Thomas, N., et al. Analysis and Interpretation of the Dust Emission of 19P/BORRELLY, 2002, Bulletin of the American Astronomical Society, 34, 868.

Thomas, N., A'Hearn, M. F. et al. Jet morphology in the inner coma of Comet 19P/Borrelly observed by the Deep Space One MICAS imaging System. Bulletin of the American Astronomical Society, 33, 1074.